NAVAL POSTGRADUATE SCHOOL
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THESIS

ASSESSING THE IMPACT OF LOW RATE INITIAL PRODUCTION ON ARMY MISSILE SYSTEM PROCUREMENT

by

Stanley M. Lewis

March 1994

Principal Advisor: Thomas H. Hoivik

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ABSTRACT
The purpose of this thesis is to provide an analysis of the impact that Low Rate Initial Production (LRIP) has upon Army missile system development. It focuses on: (1) regulatory guidance on the use of LRIP in the acquisition process, (2) the reasons programs include LRIP in their acquisition strategy, and (3) the rationale used to determine the number of systems to produce in LRIP. An in-depth analysis of how four current Army tactical missile programs have incorporated LRIP into their acquisition strategies is provided. The resulting lessons learned by these program offices is also provided. The thesis concludes that LRIP is essential to the successful transition from development to full-rate production. The current guidelines regarding the use of LRIP are vague, particularly those involved in quantity decisions. This ambiguity, however, provides the PM with flexibility to tailor his acquisition strategy. The thesis recommends that DOD promote greater contractor involvement in LRIP quantity decisions; consider ways to foster better concurrent engineering in development programs; and establish a dedicated configuration management position in each major program office.

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Assessing the Impact of Low Rate Initial Production
on Army Missile System Procurement

by

Stanley M. Lewis
Captain, United States Army
B.S., Colorado State University, 1983

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Author: Stanley M. Lewis
Stanley M. Lewis

Approved by: Thomas H. Hoivik
Thomas H. Hoivik, Principal Advisor

Richard B Doyle
Richard B. Doyle, Associate Advisor

Reuben T Harris for
David R. Whipple
Department of Systems Management

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to provide an analysis of the impact that Low Rate Initial Production (LRIP) has upon Army missile system development. LRIP will be fully defined and various methods for its incorporation into a systems acquisition process will be identified. It will also examine the rationale used to determine the number of systems to produce during LRIP. This thesis will provide lessons learned from the experiences of several programs which included LRIP as part of their acquisition strategy.

B. BACKGROUND

Previous acquisition policies have been such that delays can occur as a program transitions to a new phase in the acquisition cycle. These delays are most pronounced between the development activity and the production of the system inventory. An examination of some past directives sheds light on why such a development/production delay is inherent in our systems acquisition cycle. The Deputy Secretary of Defense, David Packard, in a 31 July 1969 memo to the Service Secretaries stated:

> There is a general deficiency in the amount of test and evaluation before we commit significant resources to production. While it is generally a mistake to schedule

> a complete break between development and production, we have tended to drift too far in the direction of concurrency, and this must be reversed.[Ref. 1]

A Blue Ribbon Defense Panel reported in July 1970:

> guard against concurrent development and production . . . Defer production decision until successful demonstration of developmental prototypes.[Ref. 1]

Finally, a General Accounting Office (GAO) Report in March 1973, "Cost Growth in Major Weapon Systems," had the following recommendations:

> Avoid concurrent development and production . . . . Adhere to orderly and sequential design, test, and evaluation, and . . . clear separation of development and production. [Ref. 1]

DOD Directive 5000.1 and DOD Instruction 5000.2 clearly state that the production phase will not be initiated until all engineering is reasonably complete and all significant design problems have been identified and solved.

Undertaking production before development is completed greatly increases program risk. It may substantially reduce the time span from concept to deployment, but it involves a commitment of substantial costs which may be wasteful in the event of program design modification, cancellation, or redirection. The use of low-rate initial production is one approach to mitigate this risk.[Ref. 2]

LRIP is defined as the production of a system in limited quantity to provide articles for operational test and evaluation, to establish an initial production base, and to permit an orderly increase in the production rate sufficient

to lead to full-rate production upon completion of operational testing.[Ref. 3] This approach reduces the Government's exposure to large retrofit programs and resulting costs while still providing adequate numbers of hard tooled production items for final development and operational test. It is also used to minimize the risk of committing the necessary resources for the production phase by allowing for test and tryout of the manufacturing equipment prior to full production release.

The test and evaluation conducted on these systems verifies that the production process provides material that meets the required technical and operational performance requirements of the system. When the decision authority feels that the system will not perform to expectation, he will direct that it not proceed beyond LRIP and further testing ensues.

The Department of Defense has entered an unprecedented period of budget and force reductions. The dramatic events leading up to the crumbling of the Warsaw Pact, thus signalling the end of the Cold War, have been the primary impetus for these reductions. These reductions are compelling DOD to reassess its procurement policies.[Ref. 12] As we progress through this period of change, the number of programs entering production will decrease as the sense of urgency diminishes. Therefore, there will be more opportunity for

LRIP. As a result, the process of determining the appropriate LRIP quantity for procurement programs requires further study.

C. OBJECTIVES

The primary objective of this thesis is to analyze the impact that LRIP has upon current Army tactical missile programs. Therefore, it will focus on three specific areas: (1) regulatory guidance on the use of LRIP in the acquisition process, (2) the reasons programs include LRIP in their acquisition strategy, and (3) the rationale used to determine the number of systems to produce in LRIP. The thesis culminates in a presentation of lessons learned in the use of LRIP by selected program offices which have incorporated LRIP as a part of their acquisition strategy. Additionally, recommendations on how to better plan for LRIP will be presented. The lessons learned and recommendations presented are not all encompassing, nor exhaustive.

D. RESEARCH QUESTIONS

1. Primary Research Question

What impact has Low-Rate Initial Production (LRIP) had on Army missile procurement programs.

2. Subsidiary Research Questions

a. What is LRIP and how is it used in the acquisition life cycle?

b. What are the primary reasons that a program enters LRIP?

c. What impact does the defense budget have on procurement programs and the use of LRIP?

d. What rationale is used to determine the proper number of systems to produce during LRIP?

E. SCOPE OF THE THESIS

The focus of this thesis is to examine the process that the Army Missile System Program Manager uses to determine how LRIP is used in his program. It will examine the reasons that a missile program enters LRIP and develop recommendations to enhance program success. In order to analyze real LRIP issues, the research included an examination of several Army Tactical Missile Programs to include: Longbow Helicopter Launched Fire and Forget (HELLFIRE), Army Tactical Missile System (ATACMS), Javelin, and Multiple Launch Rocket System (MLRS). These programs were selected because they all incorporated LRIP as a part of their acquisition strategy, and have either reached, or completed the LRIP phase of their program.

F. METHODOLOGY

This analysis includes two separate data collection efforts. First, a comprehensive literature search was conducted to assess existing LRIP guidance. Second,

telephonic and personal interviews provided insight into current practices involving LRIP. Data were acquired from relevant sources such as the Program Executive Officer (PEO), Tactical Missiles, Tactical Missile System Program Managers and selected Government Contractors. Finally, interviews were also conducted with professors and other subject matter experts at the Naval Postgraduate School concerning the acquisition process and production.

II. LOW-RATE INITIAL PRODUCTION (LRIP) IN ACQUISITION

In 1985, following media accounts of waste, fraud, and abuse in DOD's purchasing system, the president established the Blue Ribbon Commission on Defense Management (commonly known as the Packard Commission). The Commission was directed to study various DOD management policies and procedures, such as the budget process, legislative oversight, and the defense acquisition system, and to recommend improvements. In its 1986 report,[Ref. 4] the Commission made 55 recommendations to change DOD's management policies and procedures, of which 17 were aimed at DOD's acquisition organization and procedures.

The Packard Commission found that DOD's acquisition system has historically purchased weapon systems that cost more than planned, took 10 to 15 years to develop and deliver, and did not perform as expected.[Ref. 5] Additionally, they stated that the length of the acquisition cycle is "a central problem from which most other acquisition problems stem." [Ref. 6] The transition from design to production has traditionally been a troublesome area. An LRIP phase was seen as a method by which DOD could mitigate risk during this transition phase. Through its efforts to streamline the acquisition process as outlined in the Packard Commission report, DOD published DOD 5000.1, "Defense Acquisition" and

DODI 5000.2, "Defense Acquisition Management Policies and Procedures".

A. LRIP GUIDANCE

U.S. Government and DOD guidance for transitioning from development to LRIP to full-rate production is provided by several sources. The following is a brief review of these documents.

1. Department of Defense (DOD) Directive 5000.1, Defense Acquisition

This Directive, published February 23, 1991, is the top level document that, "establishes a disciplined approach for acquiring systems and material that satisfy the operational user's needs."[Ref. 7] It provides a one stop reference source for all applicable documents and regulations pertaining to weapon system development. It is the primary document in establishing policies and procedures for managing acquisition programs.

2. DOD Instruction 5000.2, Defense Acquisition Management Policies and Procedures

This Instruction, dated February 23, 1993, establishes "an integrated framework for translating broadly stated mission needs into stable, affordable acquisition programs that meet the operational user's needs and can be sustained, given projected resource constraints."[Ref. 2] It also requires that program acquisition strategies be event-driven,

with entry into LRIP and full-rate production based on accomplishing specific program results. These program results are more commonly referred to as exit criteria.

3. United States Code, Title 10

Section 2399 of this statute provides that:

- a major defense acquisition program may not proceed beyond LRIP until Initial Operational Test and Evaluation (IOT&E) is completed.
- the DOD Director of Operational Test and Evaluation submits through the Secretary of Defense to Congress that test and evaluation were adequate and that the results of test and evaluation confirm that the items or components tested were effective and suitable for combat.[Ref. 8]

4. DOD 4245.7-M, Transition from Development to Production

This manual provides assistance in structuring technically sound programs, assessing their risk, and identifying areas needing corrective action. The assistance is provided in a series of descriptive templates. Each template discusses an area of risk and then provides methods for reducing that risk. The templates are based on lessons learned from analysis of programs.[Ref. 9]

The start and completion of design, test, and production activities listed in the table are given in relationship to acquisition milestones. The manual states that program risk is introduced when a particular activity is started late or continues beyond the timeline. The table depicted in Figure 1 provides that, for minimized program

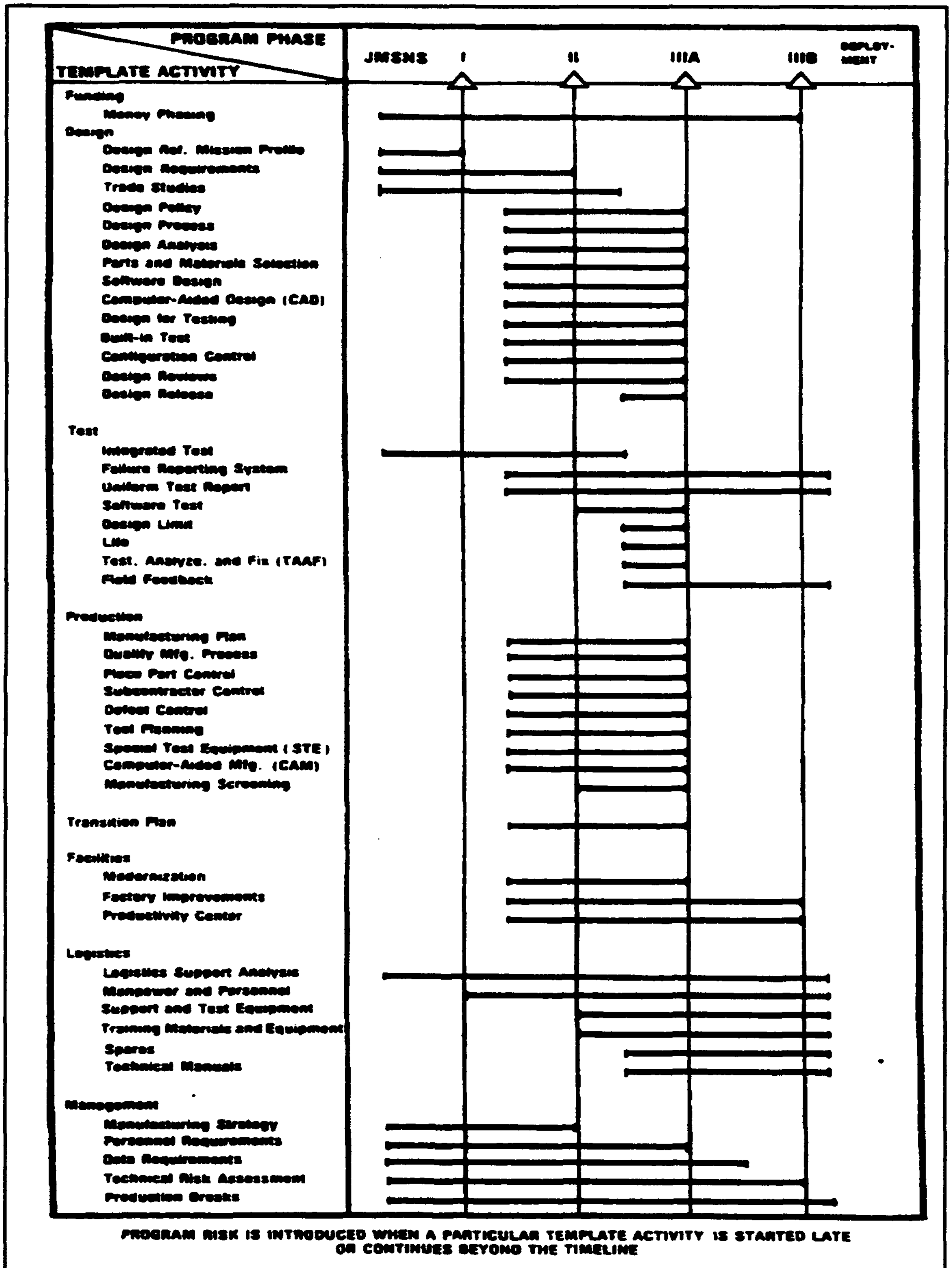

Figure 1 Template Timelines

risk, 28 of the 31 activities identified under design, testing and production be completed before the LRIP decision. In addition to the individual activity templates and activity timephasing, the manual provides the following significant insights concerning the design, test, and production efforts necessary to make a successful transition from development to production.

a. Design

Past history has shown that a high risk of failure for Government acquisition programs occurs at the outset of the design process. While some risk associated with a new technical concept may be unavoidable, this risk has been magnified by the misunderstanding of the industrial design processes necessary to turn a concept into a mature product. The templates dealing with design address the many engineering disciplines that ensure the ability of parts to endure stress, which have been historically underemphasized.

b. Testing

As the system design matures, complex testing is needed to provide confidence that the system will perform satisfactorily in the operational environment. The testing-related templates are based on test and evaluation experience of major DOD programs and the contributions of testing efforts toward reducing program risk. Attention is given to topics such as integrated test plans, operational test environments,

reliability development tests, reliability demonstration tests, initial operational test and evaluation, and applying the process of testing, analyzing failures, and implementing fixes. The guidance in the templates addresses significant testing concerns requiring management attention to reduce the risk of transition from development to production.

c. Production

Solving the manufacturing portion of the acquisition equation is a major factor in reducing the risk of transitioning to production. The history of military procurement includes many cases of proven functional designs being introduced into the manufacturing process, only to complete that process as end products that cannot support their mission requirements. The templates provide guidance for early and effective planning in areas that have been troublesome. Guidance covers subjects such as manufacturing plans and processes, quality control, subcontractor control, tool planning, special test equipment, computer-aided manufacturing, and manufacturing screening.

5. Military Standard 1521-B, Technical Reviews and Audits for Systems, Equipments, and Computer Software

The Military Standard identifies requirements for technical reviews and audits which occur throughout the acquisition process. The specific reviews and audits that

normally occur before the LRIP decision and their role in providing feedback concerning program risk include:

a. Critical Design Review (CDR)

The Critical Design Review (CDR) is conducted for each Configuration Item (CI) of a system when the detail design is essentially complete.[Ref. 10] Therefore, CDRs are normally conducted during Phase II, Engineering and Manufacturing Development (EMD). The purpose of the CDR is to:

- Determine that the detail design of the configuration item reviewed satisfies the performance and engineering specialty requirements of the development specification.
- Establish the detail design compatibility among the configuration item and other items of equipment, facilities, computer software, and personnel.
- Assess configuration item risk areas on technical, cost, and schedule basis.
- Assess the results of the producibility analyses on system hardware.
- Review the preliminary hardware product specifications.
- Determine, for software items, the acceptability of the detailed design, performance, and test characteristics of the design solution and the adequacy of the operation and support documents.

b. Test Readiness Review (TRR)

The Test Readiness Review (TRR) is conducted for each Computer Software Configuration Item (CSCI) to determine whether the software test procedures are complete and ensure that the contractor is ready for formal software testing. The review also includes assessment of the results of informal

software testing and updates to the operational support documents. A successful test readiness review is predicated on the contracting agency's determination that the software test procedures and informal test results form a basis for proceeding into formal software testing.

c. Production Readiness Review (PRR)

The Production Readiness Review (PRR) determines the status of the specific actions that must be satisfactorily accomplished before a production go-ahead decision. The review is accomplished incrementally during EMD. Incremental reviews are to be conducted at least annually and before the Milestone III Production Approval Review. In the earlier stages, the review covers gross-level manufacturing concerns such as the need for identifying high-risk and low-yield manufacturing processes or materials or the requirement for manufacturing development effort to satisfy design requirements. The reviews become more refined as the design matures, dealing with concerns such as production planning, facilities allocation, incorporation of producibility-oriented changes, identification and fabrication of tools and test equipment, and long-lead item acquisition. This review will help determine whether the program is ready for a LRIP or full rate production.

d. Functional Configuration Audit (FCA)

The objective of the Functional Configuration Audit (FCA) is to verify that the configuration item's actual performance complies with its requirements specifications. Test data are reviewed to ensure that the computer hardware or software performs as required. The functional configuration audit should be conducted on the configuration of the item that is representative of the production of the operational inventory quantities.

e. Physical Configuration Audit (PCA)

The Physical Configuration Audit (PCA) is the formal examination of the as-built version of a configuration item against its design documentation to establish the product baseline. The audit includes detailed assessment of engineering drawings, specifications, technical data, and tests used in production of hardware items and design documentation.

B. THE ACQUISITION PROCESS

DOD Instruction 5000.2 establishes an integrated framework for translating broadly stated mission needs into stable, affordable acquisition programs that meet the operational user's needs and can be sustained, given projected resource constraints. It also establishes a rigorous, event-oriented management process for acquiring quality products that emphasize effective acquisition planning, improved

communication with users, and aggressive risk management by both Government and industry. The five major milestone decision points and five phases of the acquisition process, illustrated below, provide a basis for comprehensive management and the progressive decision making associated with program maturation.

The key features and characteristics of the acquisition process are highlighted in the following paragraphs. Each milestone decision point and acquisition phase is described separately.

1. Determination of Mission Needs

The acquisition process starts with the definition of the need for a product or technology. All acquisition

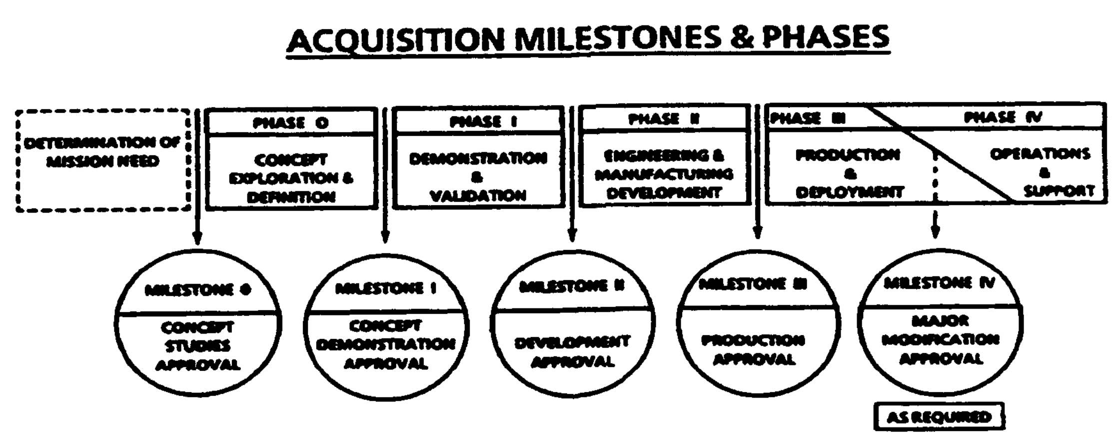

Figure 2 The Acquisition Process

programs are based on identified mission needs.[Ref. 2] A mission need may be to establish a new operational capability. It may also reflect a desire to exploit an opportunity that will result in significantly reduced ownership costs or improve the effectiveness of existing material. DOD continuously reviews the operational missions assigned to its forces to determine areas which are not adequately served by available weapons. These functional descriptions thus serve as the basis for initiation of a product development.

2. Milestone 0, Concept Studies Approval

Milestone 0 marks the initial formal interface between the requirements generation and the acquisition management systems. The objectives of Milestone 0 are to:

- Determine if a documented mission need warrants the initiation of study efforts of alternative concepts.
- Identify the minimum set of alternative concepts to be studied to satisfy the need.

Studies of alternative concepts and entry into Phase 0 may not be approved unless the milestone decision authority determines that the mission need:

- Is based on a validated projected threat.
- Cannot be satisfied by a nonmaterial solution.
- Is sufficiently important to warrant the funding of study efforts to explore and define alternative concepts to satisfy the need.

This milestone concludes with Defense Acquisition Board (DAB) approval of the MNS and the issuance of the Acquisition Decision Memorandum (ADM).

3. Phase 0, Concept Exploration (C/E) and Definition

During the C/E phase, results of exploratory development, non-government applied research and development efforts, and DOD needs are examined to identify and define new or improved systems. Competitive, parallel, short term studies by the Government and/or industry will normally be used during this phase. The focus is on defining and evaluating the feasibility of alternative concepts and providing the basis for assessing the relative merits of the concepts at the Milestone I, Concept Demonstration Approval, decision point.

A Cost and Operational Effectiveness Analysis (COEA) is performed to facilitate comparisons of the alternative concepts. Trade-offs are made among cost, schedule, and performance as a result of this analysis. The most promising system concepts will be defined in terms of initial objectives for cost, schedule, performance and overall acquisition strategy. The acquisition strategy should provide for the validation of the technologies and processes required to achieve critical characteristics and meet operational constraints. It should also address the need and rationale

for concurrency and for prototyping considering the results of technology development and demonstration.

Systems Engineering Management Plans (SEMPs), Integrated Logistic Support Plans (ILSPs), Computer Resources Life Cycle Management Plans (CRLCMPs), Test and Evaluation Master Plans (TEMPs), and other functional plans are normally initiated during this phase.

4. Milestone I, Concept Demonstration Approval

Milestone decision authorities must assess the affordability of a proposed new acquisition program at this milestone. Thus, this decision point marks the first direct interaction between the planning, programming, and budgeting and acquisition management systems. The objectives of Milestone I are to determine if the results of Phase 0 warrant establishing a new acquisition program, and establish a Concept Baseline that embodies the cost, schedule, and performance objectives applicable to the effort in Phase I, Demonstration and Validation.

A favorable decision at Milestone I establishes a new acquisition program and a Concept Baseline and authorizes entry into Phase I. The Program Management Office will be established and the Program Manager assigned within 6 months. The acquisition decision memorandum issued by the Under Secretary of Defense (Acquisition and Technology) reflects the decisions made and direction provided by the Deputy Secretary.

It also contains additional acquisition direction such as program specific exit criteria.

5. Phase I, Demonstration and Validation (D/V)

The objectives in the D/V phase are to:

- demonstrate that the technologies critical to the most promising concepts can be incorporated into system designs
- prove that the critical processes are understood and attainable
- establish a proposed baseline containing refined program cost, schedule, and performance objectives applicable to the effort in Phase II, Engineering and Manufacturing Development

It is during this phase that the principal program characteristics are validated. There is a reliance on hardware/software development and evaluation rather than paper studies. This provides a better definition of program characteristics, higher confidence regarding risks, and greater confidence in the ultimate outcome.

The acquisition strategy is then refined to identify high risk areas and the risk management approach to be used to mitigate the risk. Additionally, LRIP quantities are determined. Currently, the primary guidance available on determining the LRIP quantity is in DOD Instruction 5000.2. This document requires that LRIP quantities be limited to the minimum required for operational test and evaluation, to establish an initial production base, and to permit an orderly increase in the production rate sufficient to lead to full-rate production. This general guidance provides a great deal

of latitude to the program office in determining their LRIP quantity. The temptation exists to produce quantities greater than necessary to meet the above objectives.

6. Milestone II, Development Approval

The objectives of Milestone II are to determine if the results of Phase I warrant continuation, and to establish a Development Baseline. The milestone decision authorities must rigorously assess the affordability of the program. The Defense Planning Guidance, long-range modernization and investment plans, and internally generated planning documents of the DOD components form the basis for making this assessment.

Program risks and risk management plans must also be rigorously assessed. This is critical because of the significant resource commitment that is associated with this decision. Development approval will typically involve a commitment to LRIP. The LRIP quantities must be identified by the milestone decision authority in consultation with the Director, Operational Test and Evaluation for acquisition category I programs.[Ref. 2] For Naval vessel and military satellite programs, Title 10, U.S. Code, Section 2400(c) establishes that the following policy and procedures will be considered for determining the LRIP quantity:

- The fabrication complexity of the system
- The relatively small number to be procured and high unit cost

- The length of the production period
- The need to preserve the mobilization production base for the system
- The acquisition strategy that is most advantageous to the Government

DODI 5000.2 recommends that LRIP quantities for all other programs be determined using these same guidelines.

Once approved, the ADM authorizes the Service to prepare and release an RFP for Engineering and Manufacturing Development activities.

7. Phase II, Engineering and Manufacturing Development (EMD)

This phase is where detailed design, fabrication and testing of the system is done. This includes all items necessary for the system's support, e.g., training equipment, maintenance equipment, and operation and maintenance manuals. The intended output is a hardware/software system whose performance and reliability have been proven experimentally, along with the documentation needed to support competitive production/procurement.

Effective risk management is especially critical during this phase. To assist in managing risk:

- Resources should only be committed during this phase commensurate with the reduction and closure of risk.
- Configuration control must be established for both design and processes.
- Development and test activities should focus on high risk areas, address the operational environment, and be phased

to support internal decision-making and the Milestone III decision review.

During this phase, one or more Engineering Development Models will be produced and tested. The phase concludes with a Development Technical Evaluation (DT&E) and an Operational Technical Evaluation (OT&E). DT&E is controlled by the development agent and demonstrates that the performance, reliability, survivability, maintainability, and manability goals have been met. OT&E is controlled by the user and demonstrates that the system can perform as advertised during actual operations using user personnel. In most cases, the operational testers demand that production representative systems be provided for testing. To fulfill this requirement, many programs schedule their LRIP phase just prior to the OT&E conducted during EMD. The systems produced during LRIP are then used for operational testing.

8. Milestone III, Production Approval

The objectives of Milestone III are to determine if the results of Phase II warrant continuation and to establish a Production Baseline containing refined program cost, schedule, and performance objectives applicable to the effort in Phase III, Production and Deployment. Particular attention must be placed on:

- Assessing DT&E and OT&E results
- Establishing the most economic production rate that can be sustained, given affordability constraints

- Identifying the criteria to be used to declare when operational capability is attained
- Ensuring that planning for deployment and support is complete and adequate
- Planning for a possible transition to surge or mobilization production rates

A favorable decision at this point represents a commitment to build, deploy, and support the system. The milestone decision authority will not approve proceeding beyond LRIP until the Director of Operational Test and Evaluation prepares and submits a Beyond Low-Rate Initial Production Report to the Secretary of Defense, Under Secretary of Defense (Acquisition and Technology) and congressional defense committees.[Ref. 11]

9. Phase III, Production and Deployment

The primary objective of the production phase is to establish a stable, efficient production and support base capable of producing and delivering an effective, fully supported system. System performance, quality, and operational readiness rate will be monitored to assess the ability of the system to perform as intended and to incorporate minor engineering change proposals to meet required capabilities. The results of field experience may identify the need for major upgrades or modifications that require a Milestone IV, Major Modification Approval review.

III. PLANNING AND PREPARATION FOR LRIP

Planning for LRIP should begin early in the acquisition process. As discussed in the previous chapter, DOD Instruction 5000.2 requires that proposed LRIP quantities be determined during Phase I, Demonstration and Validation. The milestone decision authority then sets the LRIP quantity at the Milestone II, Development Approval. While no specific quantity guidelines exist, current regulations require that quantities be limited to the minimum required for operational test and evaluation, to establish an initial production base, and to permit an orderly increase in the production rate sufficient to lead to full-rate production. The design, testing, and production preparation efforts necessary to support entry into LRIP are then accomplished as part of Phase II, Engineering and Manufacturing Development (EMD). Currently, LRIP is part of the EMD phase of the acquisition process leading to Milestone III, Production Approval, for the start of production and deployment. This chapter will explore the planning process behind the LRIP effort.

A. TRANSITION FROM DEVELOPMENT TO PRODUCTION

Undertaking production before development is completed greatly increases program risk. It may substantially reduce the time span from concept to deployment but it involves a

commitment to incurring substantial costs which may be wasteful in the event of program design modification, cancellation, or redirection. Successful programs are generally characterized by a continuity of effort.[Ref. 9] In fact, DOD's policy on major weapon system acquisition stresses the importance of minimizing the time to develop, produce, and deploy major systems.[Ref. 2] By deft use of program acquisition strategy and skillful risk management, the spirit of current acquisition policies can be accommodated and still avoid a significant delay between development and production.

DOD's policy permits the Services to build concurrency into their acquisition programs. DOD has defined concurrency in acquisition strategies as the degree of overlap between the development and production processes of an acquisition program.[Ref. 2] The DOD rationale for high concurrency includes providing earlier operational capability when the need is time-urgent, avoiding technical obsolescence, and attaining efficiencies by maintaining the production process and work force.[Ref. 12] One example of concurrency is ordering, during the design phase, long lead time production materials. This pre-ordering of materials for production can prevent months, sometimes years of waiting during this transition. Another conservative alternative is incorporation of LRIP, whereby design activities continue during initial limited-rate production.

The effective planning and execution of the LRIP process is essential for a smooth transition to economical full-rate production of systems that will meet the mission requirements of planned system users. Full-rate production of a system will not be approved until the product design has been stabilized, the manufacturing processes have been proven, and production facilities, equipment, capability, and capacity are in place (or being put in place) to support the approved schedule.[Ref. 2]

B. READINESS FOR LRIP

LRIP is a critical element in the acquisition strategy for a weapon system.[Ref. 12] LRIP allows the contractor to start the system production line concurrently with on-going engineering development. Therefore, the acquisition strategy, the implementing acquisition plan, and the acquisition management process should ensure that the decision to begin LRIP is based upon demonstrated technical and performance accomplishments, not schedule or fiscal considerations. In their report on LRIP, Project No. 2AE-0026, the Office of the Inspector General found that six of the seven reviewed major defense acquisition programs entered LRIP without completing prerequisites in design, testing, and preparation for production.[Ref. 12] The identified shortfalls included:

- Significant design problems, identified in testing or technical reviews, were scheduled for resolution after entry into LRIP

- Documentation from testing or technical reviews was not planned to be available to support scheduled LRIP decisions

- Essential testing and technical reviews, designed to support the LRIP decision, were not performed

As a result, the Government incurred significant program risk from systems entering LRIP when their designs were not stable and the readiness of production processes were not verified.

1. Design Considerations

It is essential for programs to have a mature, stable design prior to entering LRIP. In order to achieve design maturity, producibility and testability must be designed into the system. The specific design objectives will vary depending on the type of system and the nature of its mission.[Ref. 13] The introduction to DOD 4245.7-M states that:

> Many programs simply cannot succeed in production, despite the fact that they've passed the required milestone reviews. These programs can't succeed for technical reasons, notwithstanding what is perceived as prior management success related to DOD acquisition policy. A poorly designed product cannot be tested, efficiently produced, or deployed. In the test program there will be far more failures than should be expected. Manufacturing problems will overwhelm production schedules and costs.

The designation of detailed design requirements in the contract is an essential objective of the Government and the contractor in communicating the needs of the project. The system specification in the definitized contract for full scale development is the foundation for the design, test, and manufacture of a weapon system. Design requirements include

a full and explicit statement of quantitative performance requirements. In addition to the more obvious requirements for system performance levels, this set of parameters includes structural static and dynamic requirements, weight, reliability, maintainability, and unit production cost. To ensure affordability, specified levels of reliability and maintainability must be consistent with realistic expectations of achievement within the limits of existing technology.[Ref. 14]

The first step in the design process is to review the requirements. After that, ideas are formulated on how to meet the cited requirements. Here, producibility is considered as part of the design criteria to be evaluated for cost-effectiveness and ease of manufacture versus the degree of compliance with the functional requirements. Producibility is an engineering function directed toward achieving a design which is compatible with the realities of the manufacturing capability of a contractor. More specifically, producibility is a measure of the relative ease of manufacturing a product. How well a contractor incorporates producibility into his design, will dictate how well the LRIP phase will go.[Ref. 16] A contractor design policy should be established which specifically outlines the considerations to be implemented during the production design process. Management participation in design and producibility reviews is critical to its success.

As the design process progresses, analytical techniques guide the continuing effort to arrive at a mature design. While the design process concerns the actual changes to the design embodied on drawings and in engineering test models, design analysis evaluates the ability of the design to meet performance specifications at low risk. Those analyses oriented to the reduction of design risk include, stress and stress/strength, worst case tolerance, sneak circuit, failure modes and effects, and thermal analyses. Inadequate risk-oriented design analyses probably cause more schedule, cost, and performance problems than any other project element. Attempting to fix design problems once LRIP has started is particularly costly. Therefore, design risk as well as performance should be carefully reviewed during design reviews. The extra time necessary to complete this evaluation will be more than recovered in the test program and the trouble free transition from development to LRIP.[Ref. 14]

The concept of a smooth transition from development into production requires that the design be frozen and documented at a point in time, and from then on, that the "configuration" be carefully controlled and documented. Only then can final planning for production, installation, maintenance, and logistics be completed. This configuration control starts prior to LRIP and must be maintained throughout the life cycle of the equipment to avoid degraded operational availability and higher support costs.[Ref. 14]

Although most defense contracts require formal design reviews, the reviews themselves often become a forum for providing an overview of the overall hardware design, rather than an in-depth technical assessment of design maturity. Design reviews must be performed by technically competent personnel in order to review design analysis results and design maturity, and to assess the technical risk of proceeding to the next phase of the development process. [Ref. 14]

2. Test and Evaluation

During the development of a weapon system, a large number of tests are conducted by subcontractors, the prime contractor, and the Government. To assure that these tests are properly time phased, that adequate resources are available, and that duplicative or redundant testing is eliminated, a properly integrated test program is required. For DOD weapon system acquisitions, successful accomplishment of test and evaluation (T&E) objectives is a key requirement for decisions to commit significant additional resources to a program, or to move from one acquisition phase to the next.

To support this, DOD 5000.2-M requires all programs to have a Test and Evaluation Master Plan (TEMP). The TEMP is a broad, top-level plan detailing all major T&E events, and is a primary document used in the OSD weapon system acquisition review and decision process. It relates the T&E effort

clearly to technical characteristics, technical risk, operational issues and concepts, system performance, reliability, availability, maintainability, logistics requirements, and major decision points. The TEMP facilitates long range planning and provides confidence in the system's readiness to proceed into the next phase of development, or into production and operational service.[Ref. 15]

a. Development Test and Evaluation

DT&E is conducted by the contractor and the program manager to assist in engineering design and development. DT&E emphasizes the use of controlled conditions with the equipment operated by well trained engineers and other contractor personnel. While the goal of DT&E is to verify attainment of technical performance specifications and objectives, feedback from DT&E provides meaningful input to risk assessment and decision making. During EMD, DT&E is used to ensure that engineering is reasonably complete and the design is mature. Therefore, the results of DT&E are used to support the decision to advance to OT&E and LRIP.

b. Operational Test and Evaluation

OT&E is conducted by an independent operational testing agency to evaluate a system's operational effectiveness and suitability. Performance trade-offs between engineering designs can be evaluated. OT&E should be conducted in an operationally realistic environment. Typical

operator and support personnel are used to obtain a valid estimate of user capability to support and use the system.

Early Operational Assessments (EOAs) are conducted during the C/E phase to assess operational impacts of candidate technical approaches and to assist in selecting preferred system concepts. EOAs are also conducted during the DEMVAL phase to evaluate potential operational effectiveness and suitability of candidate systems. They also support the MS II decision concerning commitment of funds for long-lead items or the use of LRIP.

Initial Operational Test and Evaluation (IOTE) supports the MS III decision and is conducted in a realistic tactical environment during EMD to provide a valid operational assessment of the system's operational effectiveness and suitability. Systems tested must be representative of the expected production item. It is for this reason that many programs initiate LRIP to provide articles for IOTE. If pre-production prototypes are used for both development and initial operational testing in the EMD phase, they must be sufficiently representative of the expected production items to provide a valid estimate of operational effectiveness and suitability. Often, the prototypes are handmade, then a production line manufacturing process changes the operational characteristics of the item. This can lead to significant rework, additional testing, producibility changes, and may cause schedule and cost growth.

To reduce these risks, it may be desirable to acquire a limited number of LRIP items to complete testing. There is still the risk that the additional operational testing may reveal deficiencies resulting in significant changes to the production line or article; however, these problems are mitigated by the ability to correct deficiencies prior to fielding. For major defense acquisition programs, a certification that the system is ready for full-rate production must be submitted by the Director of Operational Test and Evaluation to the Secretary of Defense and the Congress prior to a decision to proceed beyond LRIP (the Beyond LRIP Report).

3. Production Planning

Fundamental to DOD production management is the early development of a production strategy as part of the program's acquisition strategy. DOD Instruction 5000.2 requires that production engineering and producibility efforts start at Milestone I and continue through production. Key to achieving this objective is the rigorous application of fundamental engineering principles and relevant technical disciplines during development and production. DOD 4245.7-M outlines an approach to accomplish this. This approach:

- Establishes quantifiable and obtainable manufacturing design requirements based on state of the art capabilities. As a minimum, these will include requirements for design to cost, quality, production rate, and industrial base considerations.

- Identifies and evaluates the manufacturing risks in the program so that risk abatement for each can be planned and executed.

- Develops effective manufacturing processes and product design features which enhance producibility. Efforts should target design simplification, design for assembly and inspectability, design for piece part producibility, and design for system integration and test.

- Reviews the design's use of strategic or critical materials and hazardous material and investigates use of alternative materials.

- Identifies and optimizes critical product producibility features and associated manufacturing processes, such as design manufacturing tolerances and process control limits.

- Develops developmental test strategies and plans which provide for proofing or validating manufacturing processes.

The term "Producibility Engineering and Planning (PEP)," as used in DOD is identical to the term, "production planning," in the academic and industrial worlds.[Ref. 15] Initial production uncertainties need to be analyzed and contingencies addressed to avoid or minimize program disruptions and associated cost overruns as a weapon system progresses from development to production. Program Managers, interviewed during the course of this study, emphasized the importance of a good PEP program. They felt that a contractor with a good PEP program was key to the smooth transition from development to LRIP.

The purpose of PEP is to ensure that product designs reflect good producibility considerations prior to release for manufacturing. Specifically, PEP involves the engineering

tasks necessary to ensure timely, efficient and economic production. It also includes efforts related to development of the technical data package, quality assurance procedures, and evaluation of special production processes through trade studies. PEP will confirm the adequacy of the production planning, tool design, manufacturing process, and procedures before LR[illegible] begins. The PEP progress should be tracked by means of e Production Readiness Reviews (PRRs) required before production initiation decisions. DOD Instruction 5000.2 requires that production planning be specifically addressed at milestone decision points.[Ref.2]

4. Critical Decision Points

DOD has directed the use of event-driven acquisition strategies to ensure that program prerequisites are accomplished timely and in the appropriate sequence. The following are the critical decision points which precede entry into LRIP.

a. Milestone II, Development Approval

At the Milestone II decision point, DOD Instruction 5000.2 requires that the Director, Operational Test and Evaluation, determine the quantities of LRIP articles required for operational testing. Additionally, Change 1 to DODI 5000.2. dated February 26, 1993, states that authority to proceed with LRIP may require a separate program review and milestone decision authority approval at a point specified in

the Milestone II decision. DODI 5000.2 does not, however, contain specific direction on determining the LRIP quantities to be produced and exit criteria for entry into LRIP and subsequent LRIP production lots. Specific guidance in determining LRIP quantities are only provided for Naval vessels and satellites. Other programs may refer to this guidance in determining their LRIP quantities.

b. Long-Lead Funding Approval

Obligation of long-lead funding to support entry into LRIP is the second critical decision point associated with LRIP. The long-lead funding decision represents the commitment of funds to initiate production related activities. DODI 5000.2 and other acquisition guidance do not, however, establish policy for the commitment of long-lead funding for LRIP.

c. LRIP Approval

The last critical decision associated with LRIP is the approval of entry into LRIP. The 1993 change to DODI 5000.2 suggests, but does not require, a program review and milestone decision authority approval of proceeding into LRIP. It also suggests that exit criteria be established that, when successfully passed, allow the program office to expand activities or commitments during an acquisition phase. Long-lead procurement funding and LRIP are examples of such commitments.

IV. REPRESENTATIVE MISSILE SYSTEMS

An examination of how previous or existing acquisition programs have incorporated LRIP into their acquisition strategies may help to clarify its usefulness in weapon system development. The following sections present how four current Army Tactical Missile programs have done this. These programs were selected because they all incorporated LRIP as a part of their acquisition strategy, and have either reached, or completed the LRIP phase of their program. The chapter concludes with lessons learned based upon the experiences of these programs.

A. ARMY TACTICAL MISSILE SYSTEM (ATACMS)

The Army Tactical Missile System (ATACMS) is an inertial guided missile system designed to attack enemy forces at ranges beyond the capability of existing cannon and rockets. The semi-ballistic missile is fired from a modified M270 Multiple Launch Rocket System (MLRS) launcher, and uses an inertial system to guide itself accurately over the target area, where submunitions are dispensed from the warhead sections. The warhead is loaded with M74 bomblets, effective against both personnel and equipment.[Ref. 16] See Figure 3 for an illustration of ATACMS.

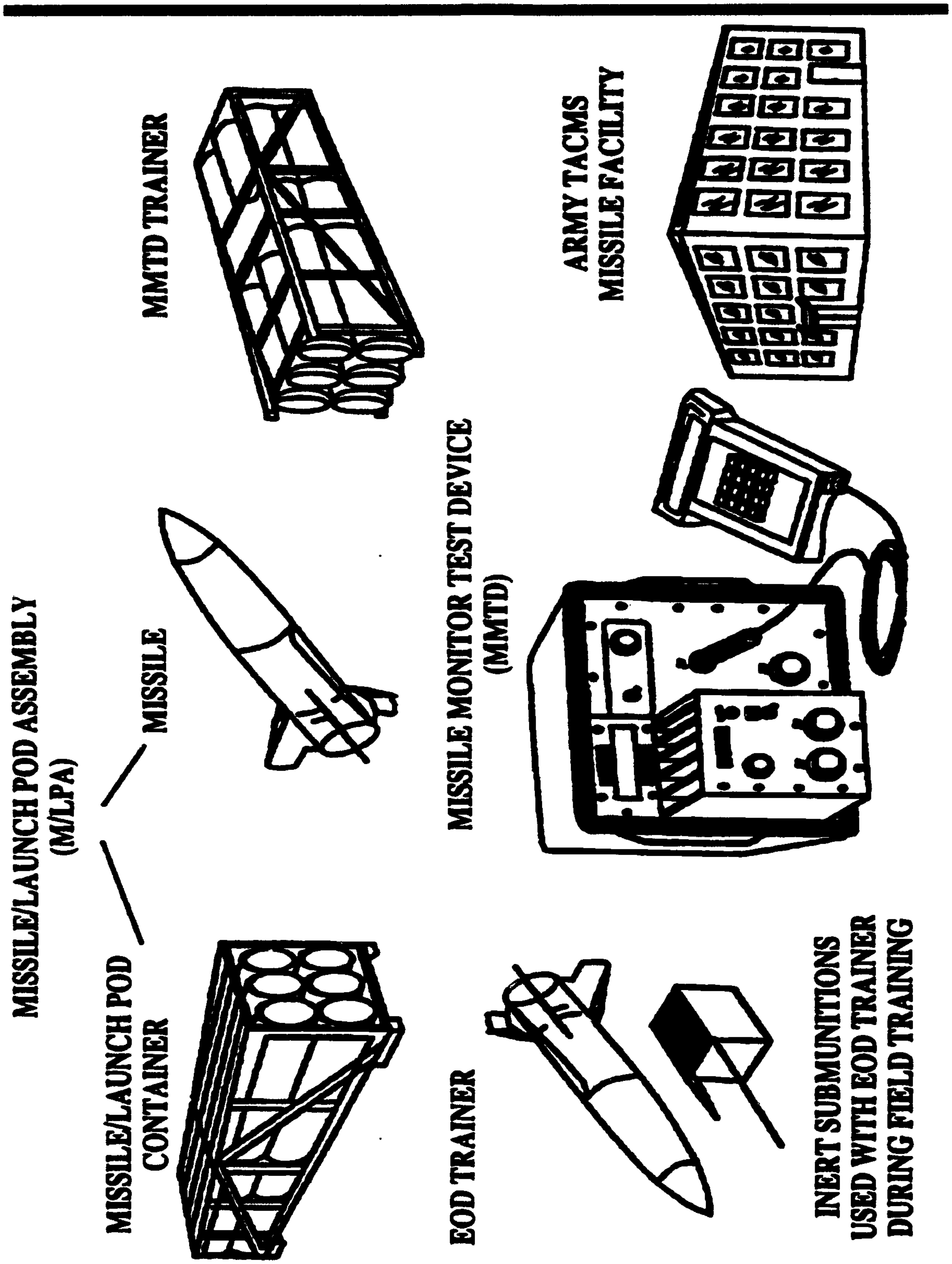

Figure 3 ATACMS

1. Program Status

The genesis of Army TACMS can be traced to the "Assault Breaker" technology demonstration program begun in 1978 by the Defense Advanced Research Projects Agency (DARPA). Formally started in 1983 as the Joint Tactical Missile System (JTACMS), the project combined two earlier studies - the Army's corps support weapon system and the Air Force conventional standoff weapon - into a joint program. Following the end of Air Force on-site participation in August 1984, the Army continued the program and changed the name.

Competitive Request For Proposals (RFPs) from industry for Full-Scale Development (FSD) of the Army TACMS Missile/Launch Pod Assembly (M/PLA or M39) and a sole-source RFP for integration of the M39 with the MLRS launcher were released in June 1985. On October 10, 1985, proposals were received from LTV Aerospace and Defense Company and Boeing Aerospace Company. LTV's Missiles and Electronics Group, formerly called the Vought Corporation, was the winner of the competition for development of the M39. In March 1986, contracts were awarded to LTV, the developer and producer of the Multiple Launch Rocket System (MLRS), for both the development and integration efforts. The contract covered a 48 month FSD program to provide design, development, fabrication, and test support necessary to obtain an LRIP decision. It also required the contractor to support the

integration of the M39 with the MLRS launcher and ground support equipment and to test the ATACMS as a total system. The program is currently in its second year of full-rate production.

2. LRIP Planning

The acquisition strategy included production options to cover all known production requirements on a not-to-exceed (NTE) price basis. The basic production option was to be utilized unless difficulties occurred in DT/OT that would require correction and additional testing. This option delineated the production of 66 M39s during LRIP followed by a full-rate production of 934 M39s.[Ref. 17] If significant difficulties were encountered during DT/OT, an alternate production program would allow for an extension of the test program. The alternate program included a second year of LRIP to resolve problems identified prior to entry into full-rate production. This option called for the production of 48 M39s during LRIP I, 60 M39s during LRIP II, and 892 M39s during full-rate production.

A number of factors drove the LRIP quantity from the PM's perspective. The primary factors were the 15 missiles needed for operational testing, while the remaining 51 missiles were determined necessary to prove-out production processes without incurring undue risk. The ATACMS program office planned for an initial deployment to U.S. Army Europe

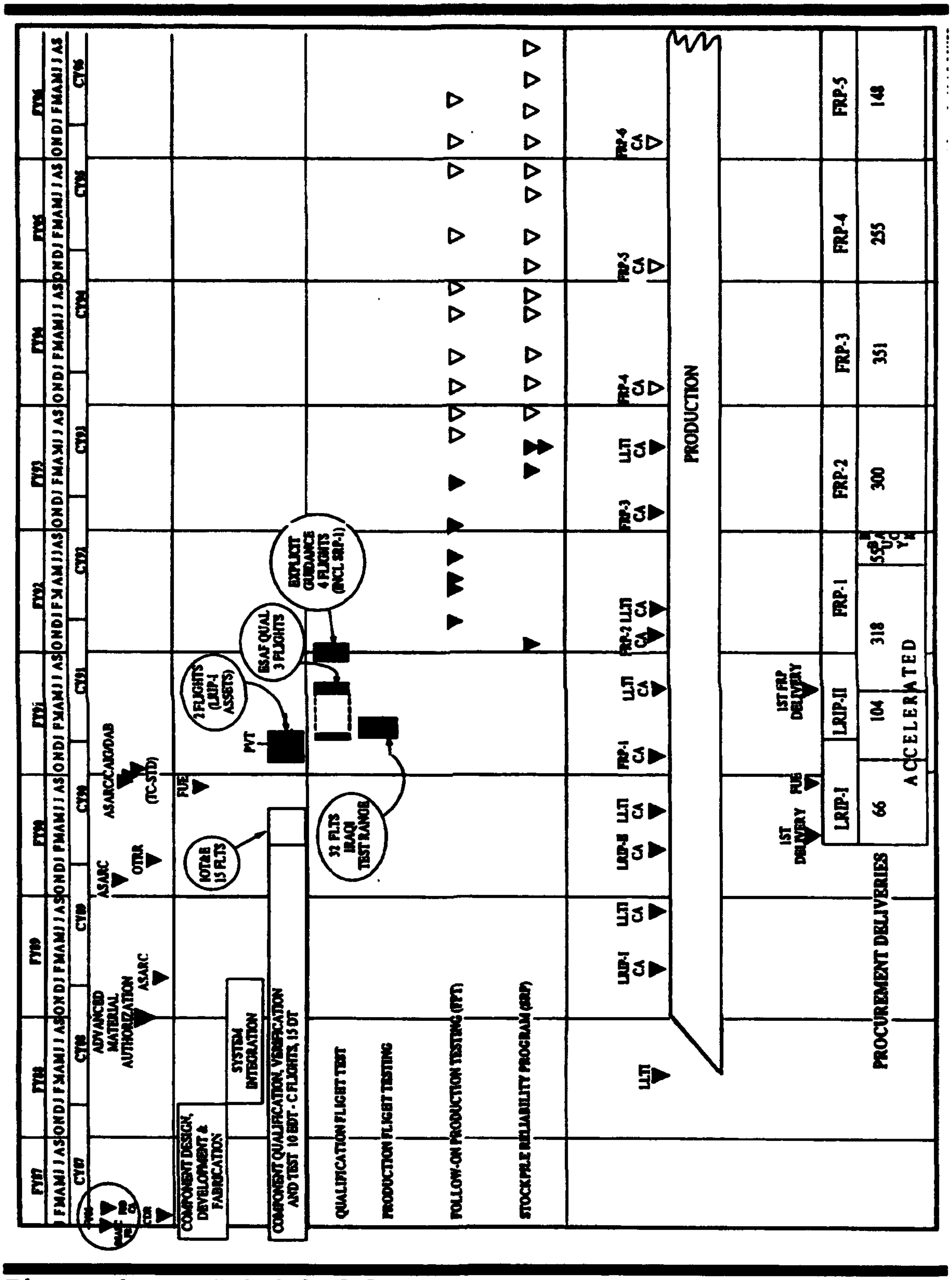

Figure 4 ATACMS Schedule

(USAREUR) with a First Unit Equipped (FUE) date of September 1990. The unit designated for first fielding was to receive the systems remaining from LRIP I after operational testing. This FUE date, however, would later become the primary schedule driver.[Ref. 18]

The program initially progressed using the basic production strategy. Just as the program was preparing to enter LRIP, however, a subcontractor providing a critical component went out of business. The resulting activity required to locate and certify a new subcontractor was a primary factor in the PM's decision to initiate the alternate production strategy, whereby a second LRIP phase would be added. Due to the last minute change in the production schedule though, it was too late to alter the LRIP I quantity of 66 M39s. Additionally, the LRIP II phase extended beyond the 48 month FSD phase. Thus, the program entered LRIP II in January 1991 instead of full-rate production. The LRIP II quantity was set at 104, a significant reduction from the original first year full-rate quantity of 276. The primary quantity drivers for LRIP II were the difficulties with the one sub-contractor and FY90/91 budget reductions.

The IOTE flight and ground tests were conducted at White Sands Missile Range, NM, and Fort Bliss, TX, from 5 Mar 90 to 8 Jun 90. The 6th Battalion, 27th Field Artillery from Fort Sill, Oklahoma had been designated as the unit to operate ATACMS during IOTE. The soldiers of 6/27 FA Bn were

subsequently trained to operate the ATACMS for operational testing. Following exposure to operational environments, a total of 15 missiles were flight tested demonstrating various fire mission requirements. All fifteen missiles flew with no in-flight performance malfunctions of any kind. [Ref. 18] These Government-conducted tests, using LRIP hardware, independently validated the contractor's testing and provided final validation of the production line and system hardware as being ready for deployment.

3. Impact of Desert Shield/Desert Storm

ATACMS was originally scheduled for deployment to U.S. Army Europe (USAREUR) with a First Unit Equipped (FUE) date of September 1990 (see Figure 4). These plans however, were altered by the Iraqi invasion of Kuwait. The requirement for a direct fire system with the range, accuracy, and destructive potential of ATACMS was identified almost immediately after the initiation of Operation Desert Shield. Consequently, 20 LRIP M39s, with supporting assemblies, were airlifted on August 26, 1990 to support Operation Desert Shield.[Ref. 16]

These LRIP assets were fielded to the 6/27th FA Bn, the same battalion that conducted IOTE. These soldiers were highly trained and experienced, proving vital to the success of this emergency fielding. If the South West Asia (SWA) deployment had occurred subsequent to the September 1990 FUE date, these first LRIP assets would have been in the hands of

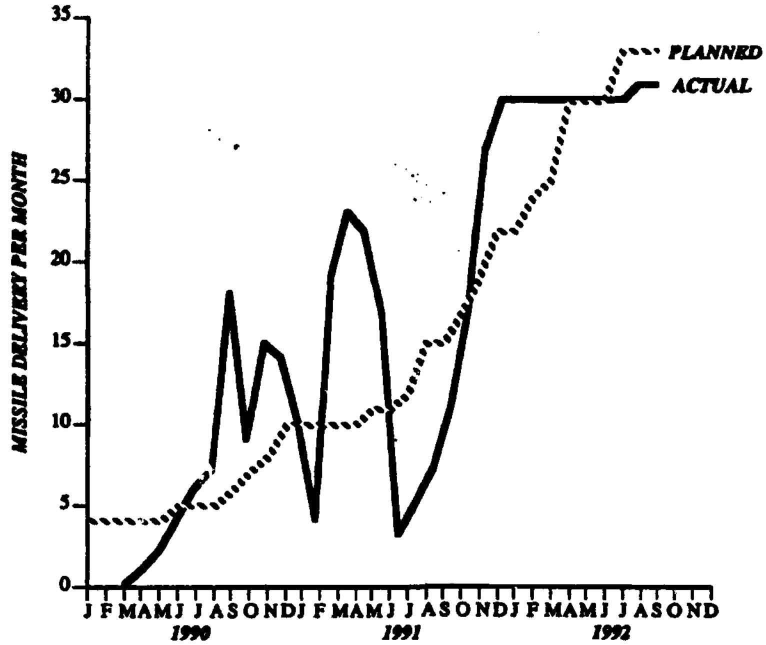

Figure 5 ATACMS Production

soldiers with significantly less training.

On 21 November 1990, Army Central Command (ARCENT) increased the quantity of missiles required to 108. In January 1991, the Vice Chief of Staff requested expedited delivery of all available assets. Through the combined efforts of the Army TACMS Project Office, the contracting officer, and the contractor (LTV), LRIP phases I & II were accelerated to increase missile deliveries from 66 to 86 before the end of the calendar year. By the end of the war, 105 missiles were in SWA. The impact of Desert Shield/Desert Storm on LRIP is illustrated in Figures 4 and 5.

The result of this acceleration was an increased number of Engineering Change Proposals (ECPs), Request for Deviations (RFDs), and Request for Waivers (RFWs). Configuration Control was found to be lacking, resulting in changes being accomplished on a missile by missile basis. With very limited time available for the Government to review and evaluate ECPs/RFDs/RFWs, the program manager co-located contractor and Government teams at the production facility to accept and ship the missiles directly to SWA. The PM feels that the 30+ successful firings of ATACMS in SWA was testimony to the quality of work by the personnel on the floor at contractor and vendor facilities.[Ref. 19]

4. Summary

The ATACMS PM incorporated LRIP as a part of the initial acquisition strategy. Although a number of factors drove the ultimate LRIP quantity, the primary drivers were operational testing requirements and available budget. The unique circumstances surrounding the use of ATACMS in Operations Desert Shield/Desert Storm had a significant impact upon the LRIP phase. The resulting acceleration in the LRIP production rate magnified a weakness in the area of configuration management.

B. LONGBOW HELICOPTER LAUNCHED FIRE AND FORGET (HELLFIRE)

The Longbow HELLFIRE missile system is employed by the AH-64 Apache helicopter. HELLFIRE is an acronym for Helicopter

Launched Fire and Forget Missile. Through considerable use, the acronym has become the common title of the system. In fact, the HELLFIRE system is not presently configured as a "fire and forget" weapon. The system utilizes semiactive laser or radar guidance against heavily armored vehicles at longer stand-off ranges. It provides accurate fire on targets acquired and designated autonomously by the attack helicopter. Targets can also be remotely designated by ground observers, other attack helicopters, and aerial scout helicopters.

1. Program Status

The current program, Longbow, is the continuing improvement of a missile system that originated in 1976-1981 as the HELLFIRE Modular Missile System. In January 1991, a 54 month EMD contract was awarded to Martin Marietta for the development of the missile system. The integration of the system with the AH-64 Apache will be done by McDonnel Douglas Helicopter Company.

2. LRIP Planning

There was concern within the program office as to the definition of LRIP. The PM's objective in determining the quantity to produce during LRIP was "lowest cost, best technical".[Ref. 21] They considered the statutory definition contained in Title 10, U.S. Code, Section 2400 which states:

> . . . low-rate initial production with respect to a new system is production of the system in the minimum quantity

> necessary; (1) To provide production-configured or representative articles for operational tests...; (2) To establish an initial production base for the system; and, (3) To permit an orderly increase in the production rate for the system sufficient to lead to full- rate production upon successful completion of operational testing.[Ref. 20]

The program office felt this definition did not sufficiently quantify the amount they were to produce during LRIP. Upon conferring with the PEO, they determined that their maximum LRIP quantity should not exceed ten percent of the total planned production quantity, or one-third of the maximum production rate.[Ref. 21] The project office felt that an LRIP quantity that exceeded these guidelines would be

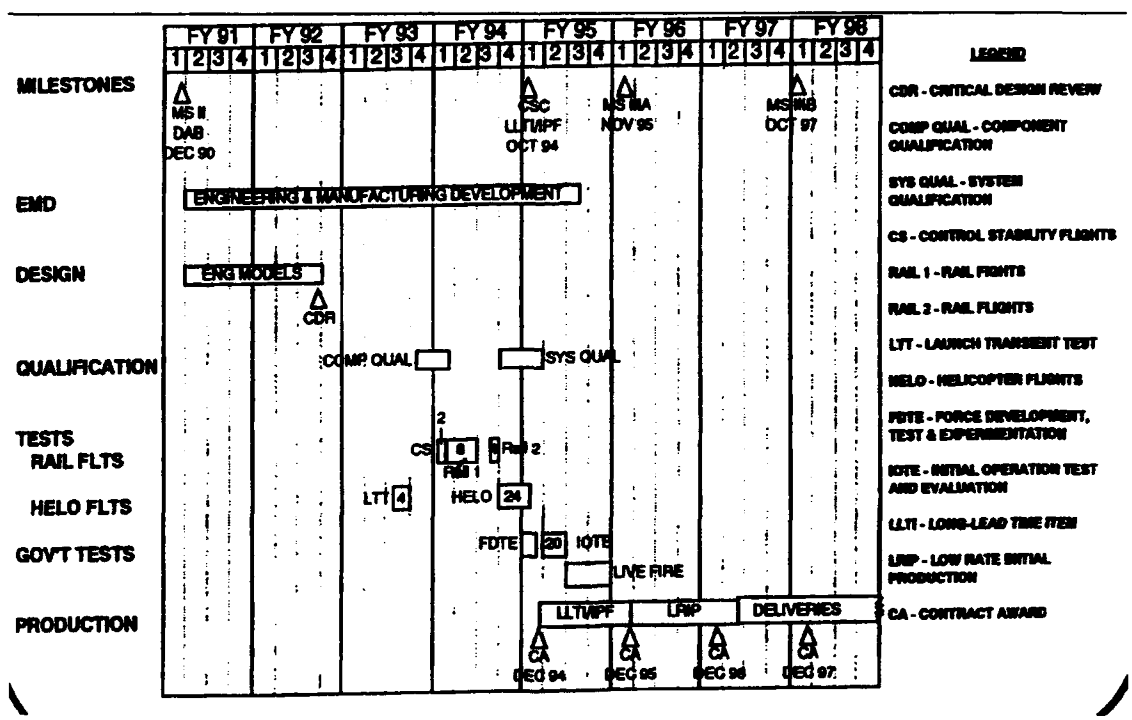

Figure 6 Longbow HELLFIRE

interpreted as too risky and costly, thus, not acceptable to Congress or DOD. As a result, the PM incorporated two LRIP phases in which a total of 1,414 missiles would be produced out of a total planned production quantity of 13,311. The contractor was involved from the standpoint of how and when LRIP would be implemented in order to provide for a smooth transition into production. Although conversations were conducted with the contractor regarding the LRIP quantity, budget constraints were the primary deciding factor.

The HELLFIRE PM structured the program such that a clear separation exists between EMD and LRIP. IOTE will be used to obtain an LRIP decision (commonly called the MS IIIa decision). Therefore, IOTE will be conducted using missiles not produced on an LRIP line. The 20 missiles required for IOTE will be produced on a pilot production line during EMD. This production line is similar to an LRIP line except that funding will come from the R&D account rather than from production, and the production quantity will be especially small. During the first LRIP phase, 364 missiles will be produced over a 22 month period. Since IOTE was conducted using missiles produced on a different line, the first 24 missiles produced off the LRIP I line will undergo a First Article Test (FAT). This test is required to verify that the production line is producing missiles representative of the missiles that were tested during IOTE. Any changes resulting from the FAT will be incorporated into the remainder of LRIP

I production. The planned production for the second LRIP phase is 1,050 missiles over a period of 12 months. In this case, LRIP II will allow the contractor to gradually ramp up his production rate, and will allow for further production proveout. All of the missiles produced during LRIP I & II, except those needed for FAT, will be fielded to operational units. Following LRIP II, the program will enter full-rate production for eight years whereby approximately 1500 missiles will be produced each year.

3. Summary

The Longbow HELLFIRE program presents a detailed account of the process acquisition programs go through as they struggle to determine the LRIP quantity. Although an exhaustive review of all current guidance was conducted, budget constraints were the principal deciding factor. This program also illustrates a more conservative use of LRIP, in that IOTE will be used to support the decision to start LRIP rather than using LRIP to manufacture articles for IOTE.

C. JAVELIN

The Army is developing the Javelin to replace the Dragon II antitank weapon. The Javelin is intended to be a medium-range, man-portable anti-armor system for use in rapid deployment operations, rough terrain, and air assault operations. Its mission is to defeat tanks and other targets expected on the modern battlefield. The system consists of a

missile and a reusable Command Launch Unit (CLU) for target acquisition and surveillance.

The Javelin is expected to offer more than twice the Dragon II's maximum range (2,000 versus 950 meters) and enhanced lethality. Also, unlike the Dragon, the gunner will not guide the Javelin's missile after firing. This will enable the gunner to rapidly fire a second missile, or take cover.

The autonomous guidance capability relies on an advanced imaging infrared device, referred to as the focal plane array sensor, to detect the thermal energy emitted by a target and provide tracking information to the guidance system. Before firing the missile, the gunner can select either a flat trajectory, to attack targets under cover such as bridges, or a lofted trajectory, to attack the more vulnerable top of a tank. See Figure 7 for an illustration of the Javelin system.

1. Program Status

The Javelin program entered the EMD phase in June 1989. The joint venture team of Texas Instruments and Martin Marietta was awarded a $481.0 million, 36-month EMD contract. After encountering significant problems in developing the missile's focal plane array component, however, the PM and the contractor determined that the 36-month development schedule could not be met. In September 1991, the Defense Acquisition Executive (DAE) approvec the Army's restructured 54 month

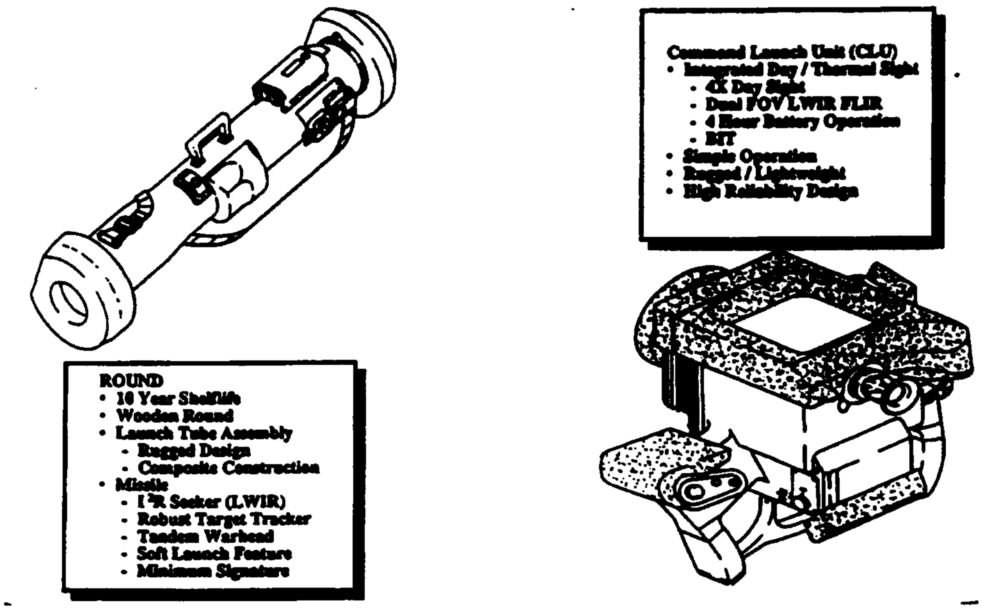

Figure 7 Javelin System

development program. The restructured program extended the current EMD program by 18 months to December 1993 and delayed initial fielding by 26 months to April 1996. It also delayed IOTE by 20 months to October 1993. The Javelin PM and DOD test officials assessed the restructured schedule as having moderate risk because of the limited time available to redesign and retest. Production engineers feel that configuration management of the system will be especially challenging as the program enters LRIP.

Due to the problems associated with the focal plane array, the unit cost of this component is increasing. In September 1991, the DAE established that the cost of producing

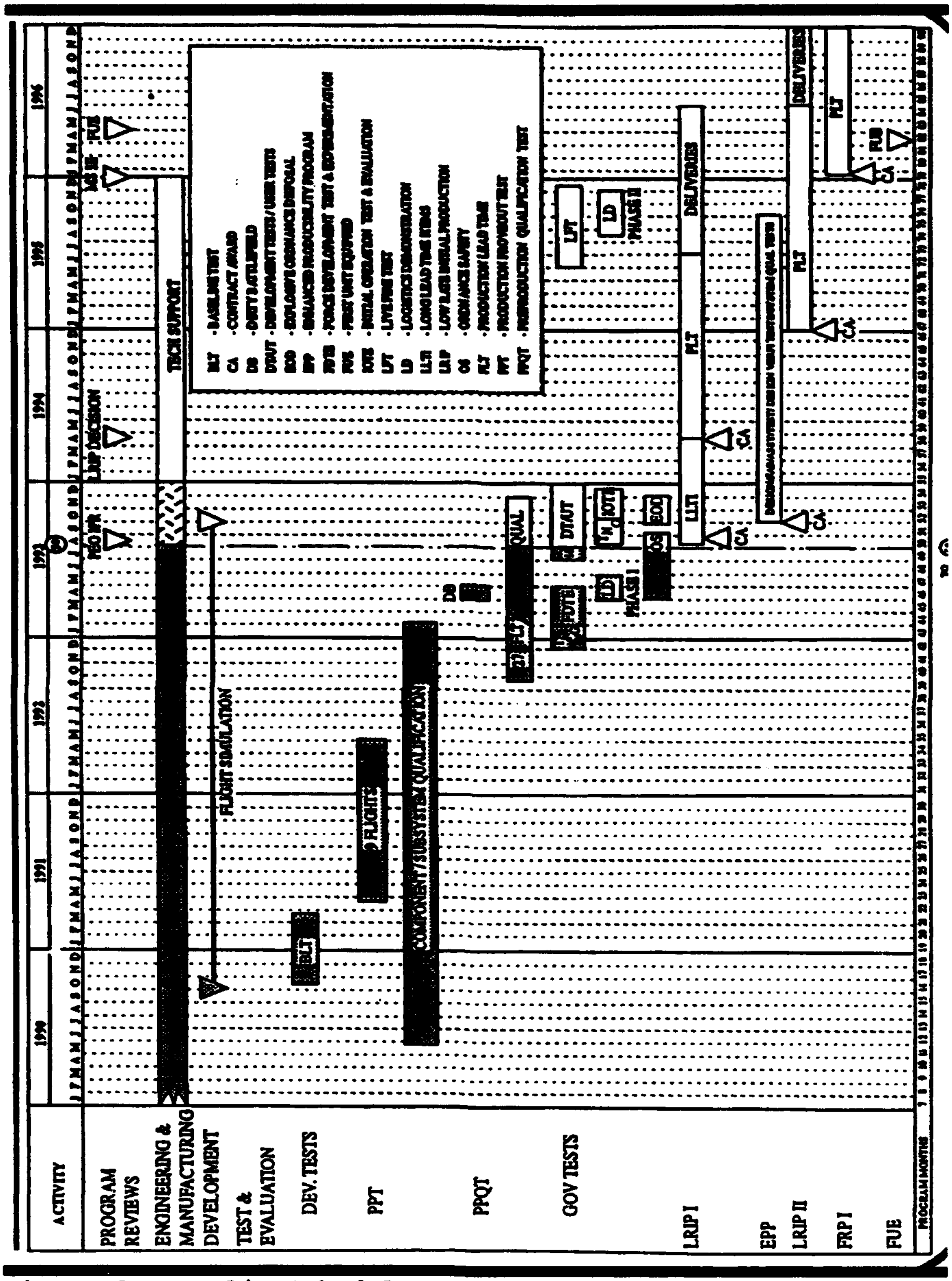

Figure 8 Javelin Schedule

this component must average no more than $12,500 (constant 1992 dollars) to meet production estimates and to ensure that the Javelin remains cost effective.[Ref. 22] With development unit costs currently at $63,000, an ambitious decrease of 62 percent is planned before LRIP, with additional significant reductions required to attain the overall average cost of $12,500. DOD systems and production analysts believe that the planned cost reductions may be optimistic.[Ref. 22] High unit costs of the Javelin system will likely have an adverse effect on the ultimate production quantity.

Reductions in the Army force structure have led to a corresponding reduction in the budget available for weapon procurement. The Army, however, has not reduced its planned Javelin procurement. In response to the reduced budget, the Army stretched the full-rate production timeline from 6 years (15,000 per year) to 11 years (8,500 per year). Future budget reductions are expected to reduce this production rate even further.

2. LRIP Planning

The Javelin program manager incorporated LRIP as a part of the initial program acquisition strategy. This program utilizes two LRIP phases during the latter part of EMD. The second LRIP phase will start prior to the end of LRIP I. This will allow for production continuity while the system undergoes follow-on operational testing.

[Ref. 23] The total planned production objective is 58,000 Javelin missiles and 5,000 CLUs. During the first LRIP phase, 1000 missiles will be produced over a period of 26 months. This quantity was based on training, testing and budgetary considerations. Additionally, missiles from LRIP I will constitute the initial fielded systems. During LRIP II, 2009 missiles will be produced over a period of 30 months.

Although the PM's theory behind this quantity was to allow for a smooth ramp up to full rate production, budget constraints are now the primary quantity driver for LRIP II. Therefore, the PM anticipates that the contractor's increasing unit cost will ultimately drive the LRIP II quantity down to approximately 750 missiles. The contractor was involved in LRIP discussions only from a timing perspective so that he could properly plan for facilitization given the anticipated production rate.

3. Summary

Although the Javelin PM carefully incorporated the use of LRIP in his initial strategy, subsequent developments are having a profound effect on planned accomplishments. Design problems with the focal plane array component have not only extended the EMD phase by 18 months, but have raised concerns with configuration management as the start of LRIP nears. Support of the program is also fading as the military

downsizes. The resulting budget reduction will most likely impact upon the LRIP quantity.

D. MULTIPLE LAUNCH ROCKET SYSTEM (MLRS)

The MLRS is an all weather, indirect fire system consisting of a 12 round rocket launcher mounted on a highly mobile, tracked vehicle (M270) equipped with a man-rated cab and an on-board computerized fire control system. The system is designed to supplement cannon weapons available to U.S. division and corps commanders for the delivery of a large volume of fire power in a very short time against critical, time-sensitive targets. The system is used to defeat enemy artillery, air defense, other light material, and personnel targets at ranges over 30 kilometers.

1. Program Status

Although the current program includes a variety of system upgrades, the basic system, known as phase I, is the only phase of the MLRS program which has transitioned all the way to full-rate production. It consists of the launcher with the dual-purpose, improved conventional submunition warhead (M77 rocket). See Figure 9 for an illustration of the MLRS.

In a memorandum to the Secretary of the Army, dated 14 February 1977, the Secretary of Defense authorized the Army to proceed with development of the MLRS with the dual-purpose submunition warhead. The Secretary of Defense also directed the Army to continue to study ways to accelerate production

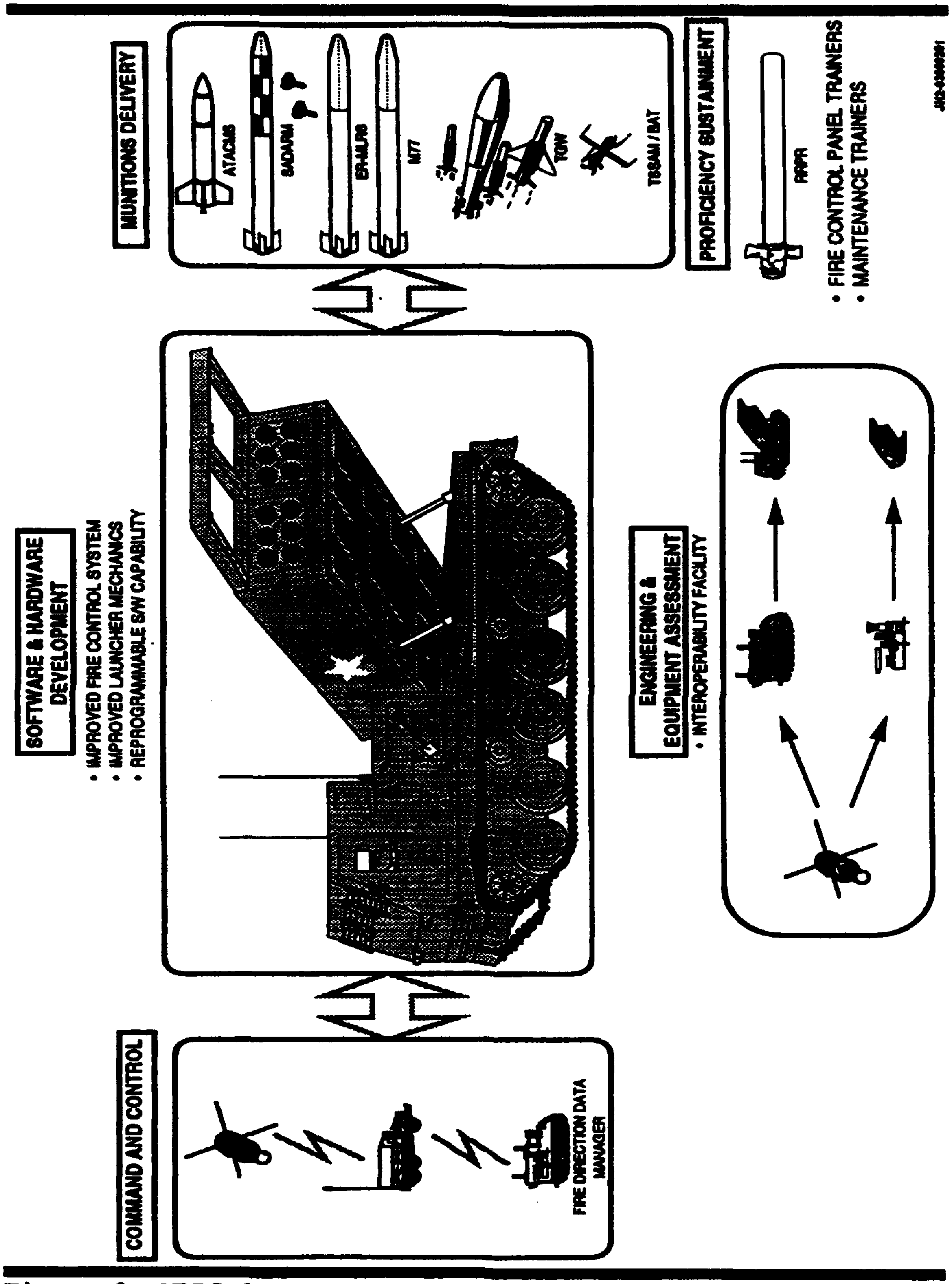

Figure 9 MLRS System

and to give high priority to standardizing the weapon system with the systems of key NATO allies.[Ref. 24] The MLRS acquisition strategy, therefore, emphasized competition, international cooperation, accelerated development, an intensive design-to-cost effort, and provisions for system growth potential. This strategy was considered responsive to the congressional request to deploy the system in five years.[Ref. 24]

Phase I started in September 1977, with Boeing and Vought (now LTV) selected as the development contractors. The two prime contractors were tasked with system development and integration responsibilities which included design, fabrication, and testing of the MLRS hardware, and development of supporting documentation. As can be seen in figure 10, the program entered FSD and LRIP simultaneously, an action no longer allowed by statute. The design, development and testing programs were tailored to the unique requirements of the accelerated project. Testing conducted during DEMVAL had to provide assurance that the system would satisfy performance requirements after maturation (EMD). Such assurance was considered necessary before commitment to LRIP, in parallel with EMD. DT II/OT II tests, which normally provide the data to support decisions for transition into LRIP, were conducted in a combined DT I/OT I. Therefore, the DT I/OT I tests were more comprehensive than those normally conducted during DEMVAL. Instead of testing on "brassboard" or surrogate

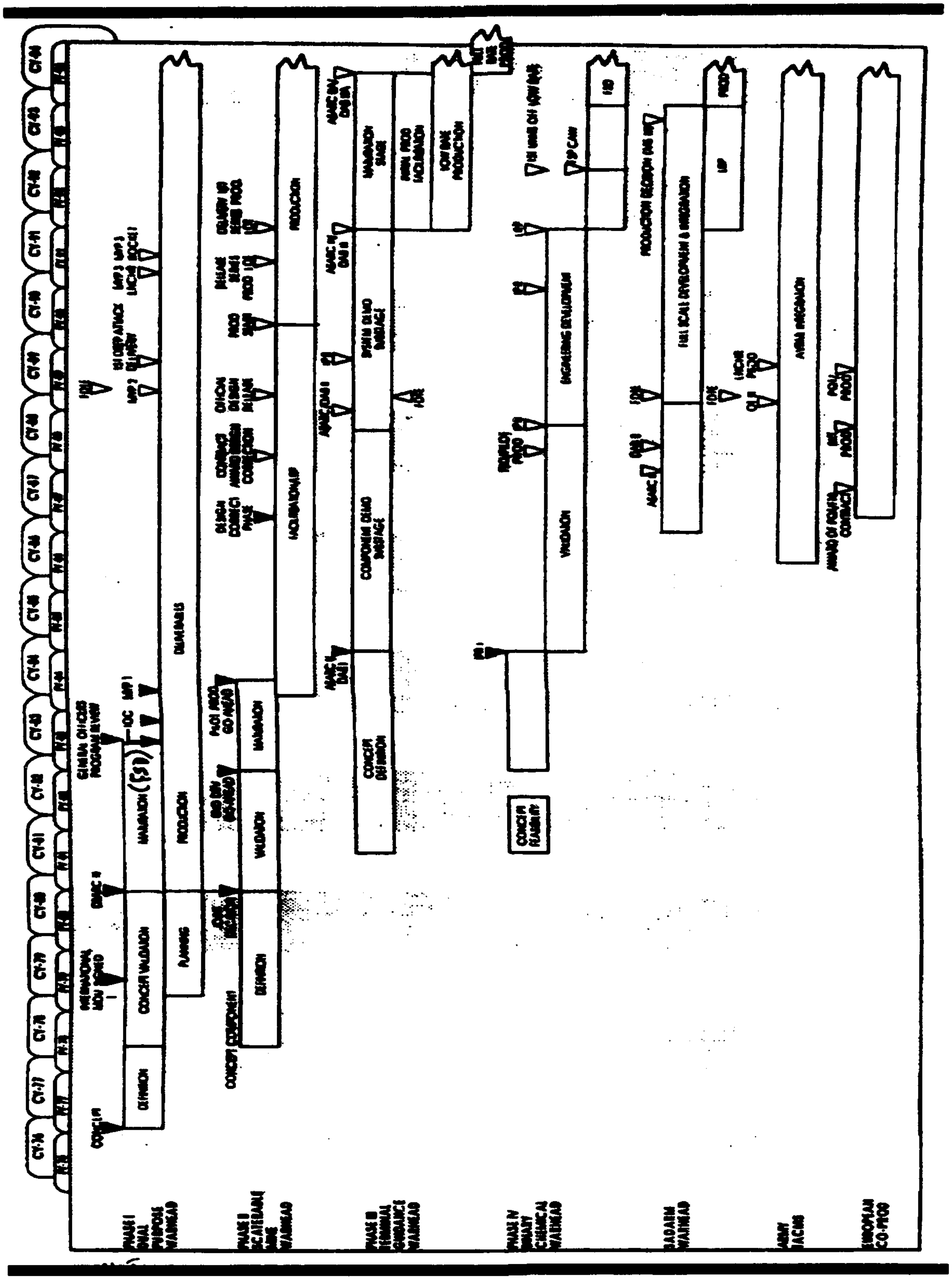

Figure 10 MLRS Program

hardware which simulates technical and operational characteristics, engineering prototype hardware was designed and fabricated for DT-I/OT-I testing. These system designs represented the production configurations and successfully demonstrated the potential of the MLRS to meet the specified performance requirements with no major design changes. Minor hardware design changes were planned for and implemented early in the EMD/LRIP Phase.

Due to the accelerated schedule, the PM and Deputy PM recognized the need for disciplined, yet innovative, Configuration Management (CM) procedures. Therefore, in December 1976, during concept definition, a person with prior CM and engineering experience was assigned as Chief, CM Office, to plan and execute a formal CM program. His experience with earlier, similar systems helped in the preparation of technical documentation required to identify hardware and software baselines. These baselines were used as approved points of departure for control of future changes to the design and performance requirements.

2. LRIP Planning

The program used LRIP to facilitate the rapid development and urgent need to field a long range, heavy bombardment rocket system. The schedule was being driven by the IOC date. As a result, the quantities produced during LRIP were to help validate the production line, for

operational testing, and to meet IOC. The strong congressional and DOD support of the program allowed the PM considerable freedom in determining the LRIP quantity. His decision was to build 34 launchers and 1,340 rockets for testing and initial fielding. Since the R&D and LRIP contracts were competitive and awarded concurrently, no contact was allowed between the program office and the bidding contractors. The contractor was therefore not involved in the LRIP planning.[Ref. 25]

The LRIP phase, as a result of being concurrent with the EMD phase, lasted over 4 years (1980-1983). During LRIP, the first 10 launchers and 312 rockets produced were used for Production Qualification Testing (PQT) and operational testing (OT III) conducted from February through September 1982. The successful completion of these tests led to a Defense Systems Acquisition Review Council (DSARC) IIIa decision to enter full-rate production in January 1983. The remaining 24 launchers and 1,028 rockets produced during LRIP were either deployed to the first two IOC batteries, or used to support training programs.

3. Summary

The MLRS program is unique in this study in that the original development program spanned the period between 1977 and 1983. During that time, existing statutes did not prevent consideration of meeting an IOC date in determining LRIP

quantities. This, along with an urgent need for the system and strong congressional and DOD support, compelled the PM to initiate LRIP and EMD concurrently. LRIP was designed to validate the production line, provide articles for testing and meet the established IOC date. The PM maintained control of design changes through aggressive adherence to configuration management procedures.

V. LESSONS LEARNED

This chapter presents the principal lessons learned based on the review of DOD's acquisition policies and from the study of the four Army Tactical Missile programs.

A. DISCIPLINED CONFIGURATION MANAGEMENT IS VITAL

The primary objective of the EMD phase is to validate and release a technical data package for full and open competition in the production phase. Consequently, prior to the end of EMD, a firm production data package is not available. The program office must therefore determine what technical criteria it will use as a basis for awarding an LRIP contract. This is a particularly difficult task which requires most programs to "freeze" development in the form of an interim production baseline. Control of the resulting design changes have proven particularly challenging.

The two programs that have progressed through LRIP, ATACMS and MLRS, provide contrasting results from their experience with configuration management. As an accelerated project from the beginning, the MLRS program office recognized the need for disciplined and vigorous adherence to CM procedures. The PM's subsequent assignment of an experienced engineer to be Chief of CM was the primary act to address this need. This individual's efforts to identify and document the functional

and physical characteristics of each configuration item, control changes to those characteristics, and to report change processing and implementation status, was key to the success of the program as it transitioned from development to LRIP. The ATACMS program office, on the other hand, experienced a surge in demand just as the program was progressing through its first controlled LRIP phase. The resulting acceleration in the LRIP production rate resulted in a situation where drastic measures were required, on both the contractor's and the PM's part, to maintain control over CM.

The Javelin program office, although not yet in LRIP, is becoming concerned with CM as a result of their difficulties with the development of the focal plane array component. The concern involves additional funds needed to compensate the contractor for the production risk he is assuming. [Ref. 25] The contractor may have to change purchase orders or scrap material to accommodate any design changes during LRIP. It remains to be seen whether their CM will be effective in controlling costs as they transition into LRIP.

The experiences of these few missile programs indicate that disciplined CM procedures are required to reinforce program stability and control costs during the turbulent transition between development and production. Proper planning for CM by the program office early in the EMD phase will help to prevent surprises during LRIP.

B. LRIP QUANTITY DRIVERS

DOD Instruction 5000.2 requires that LRIP quantities be limited to the minimum required for operational test and evaluation, to establish an initial production base, and to permit an orderly increase in the production rate sufficient to lead to full-rate production. This guidance provides a great deal of latitude to the program office in determining their LRIP quantity. The temptation exists to produce quantities greater than necessary to meet the above objectives.

All of the studied program offices struggled to some degree in determining their LRIP quantity. This occurred because current guidance is simply not explicit enough. Compounding this lack of guidance is the lack of involvement of the contractor in the quantity decision. As a result, program offices had to independently rationalize their chosen LRIP quantity.

Although independent, each program office ended up relying primarily on the quantity required for operational test, and their projected available budget as the primary quantity drivers. In an effort to rationalize their projected, "best" LRIP quantity, the HELLFIRE program developed the rule of thumb that maximum LRIP was no more than 10 percent of the total production quantity and/or one-third of maximum production rate. The foundations of this rule lie primarily on budgetary concerns. ATACMS quantity drivers were initially

IOTE and production prove-out. This planning was later superseded by the fielding requirements for Desert Shield/Desert Storm. The Javelin quantity is based primarily on training, testing and budgetary considerations. The current shrinking procurement budget is having a particularly profound effect on the Javelin as the PM now expects his original LRIP quantity to be paired by more than half. The MLRS program was unique in that previous statutes allowed for the consideration of fielding in determining the LRIP quantity. This, along with strong congressional and DOD support of the program, provided the PM with considerable latitude in determining the LRIP quantity.

Note that, with the exception of the MLRS program, none of the programs mentioned quantities required for initial fielding as an LRIP quantity consideration. This is appropriate since it is in violation of current statutes to do that. However, each program has used, or is planning to use, LRIP articles to meet an IOC/FUE date. This date is of such importance that, in the case of the ATACMS and Javelin programs, meeting the IOC/F[illegible] date starts driving the schedule. Thus, any difficulties encountered in the development or testing programs that cause schedule delays quickly achieve crisis proportions. In no case was the contractor, the organization with the most information concerning producibility, involved in LRIP quantity decisions.

Perhaps the most profound idea was put forth by an anonymous production engineer who suggested that the LRIP quantity should only be that quantity required for operational testing. His reasoning was that if operational testers can validate that an LRIP produced system meets all testable criteria, then by definition, the production line has also been validated.

It is evident that LRIP quantities are primarily driven by operational testing requirements and available budget. Additionally, although not specifically used as a quantity driver, LRIP articles used to support an IOC date ultimately have a significant impact upon the LRIP phase.

C. SOUND CONCURRENT ENGINEERING IS CRITICAL

Concurrent engineering was frequently mentioned as key to a successful transition from development to production. Program Managers who expressed that they had good concurrent engineering had Government contractors who had experienced the pain of not doing good concurrent engineering in a previous program.

DOD 4245.7M was issued in September 1985 to help Program Managers better understand the timing of the disciplines of design, test, and production. It is essential to incorporate production engineering, for example, early in the EMD phase. Program Managers must also consider the fact that LRIP articles are being produced by production people, not

engineers, as is the case in EMD. It is helpful to develop methods for production through the use of pilot production lines, as the HELLFIRE program is doing, to prove-out production processes. Use of production configured tooling, test equipment, production documentation, and production personnel when building EMD hardware is especially helpful.[Ref. 26]

The ATACMS and Javelin PMs, in particular, felt that sound concurrent engineering (between design and production) is the key to having a smooth LRIP phase. It's not enough though, for Army Program Managers to recognize this. A lack of good concurrent engineering by their Government contractors resulted in goals for the EMD phase that were too optimistic. This led to difficulties in getting the production quantities to planned levels in LRIP as they tried to get the "bugs" worked out.

D. LRIP GUIDANCE PROVIDES FLEXIBILITY

The flexibility of current LRIP guidance allows for changes due to technical difficulties as well as changes in the political fortunes of the programs. For instance, although DODI 5000.2 allows a program to enter LRIP to produce articles for operational testing, the Javelin and HELLFIRE programs elected a more conservative strategy and chose not to do this. Additionally, congressional and DOD support of a program, and the resulting available budget, produce profound

changes to the best planned programs. The MLRS and ATACMS programs rode a swell of financial support for their programs as they executed their acquisition strategy. Their LRIP quantities reflected this support. Conversely, the Javelin and HELLFIRE programs instead chose a more conservative strategy and elected to produce IOTE articles on a pilot production line. They will wait on the results of IOTE to support the decision to start LRIP.

All program office personnel interviewed in the course of this thesis felt that the current guidance regarding LRIP is good. Most felt that any changes designed to further specify the use of LRIP in acquisition programs would hinder their ability to tailor the LRIP phase to the specific needs of their program.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. General Conclusions

Undertaking production before development is completed greatly increases program risk. The use of LRIP, whereby design activities continue during initial production, allows programs to transition smoothly from development to production without incurring significant delays. The effective planning and execution of the LRIP process is essential for a smooth transition from the EMD phase to economical full-rate production. Planning for LRIP should begin early in the acquisition process and should follow current guidelines.

The current guidelines regarding the use of LRIP are vague, particularly those involved in quantity decisions. This ambiguity however, provides the PM with the ability to tailor his acquisition strategy given the varying technologies and political fortunes of the current acquisition environment. Currently, available budget is having a significant impact on LRIP quantity determinations.

All of the interviewed PMs agree that an Army missile development program cannot successfully transition from development to full rate production without LRIP. In fact, all of the programs presented in this thesis incorporated

multiple LRIP phases to mitigate the risks associated with this transition from development to production. Multiple LRIP phases allow greater freedom in making design changes and quantity adjustments.

2. **Specific Conclusions**

- **Disciplined Configuration Management (CM) procedures are required to enhance program stability and control costs during LRIP.** One of the greatest challenges in planning for LRIP involved the development and use of a reasonably firm technical baseline to award the LRIP contract. The MLRS is an excellent example of a program that, due to rigorous adherence to CM procedures, successfully navigated the transition from development to production with an accelerated schedule. Conversely, the ATACMS program had to initiate dramatic measures to maintain their production rate as they accelerated their production rate to meet SWA requirements.

- **An over commitment to production can easily occur if proper analysis is not conducted prior to the LRIP quantity decision.** The quantity guidance delineated in DODI 5000.2 provides a great deal of latitude to the program office in determining their LRIP quantity. Although quantities required for testing are easily determined, the quantities required for production prove-out require careful study. Contractor input, while essential, is usually not sought during LRIP quantity decisions. As a result, each missile program developed an independent rationale for their selected LRIP quantity. In every case, quantities produced above those needed for testing were limited only by available budget.

- **Political favor weighs heavily on how LRIP is used in a program.** The political process surrounding acquisition programs affects the timing and quantity considerations of LRIP. The PM with tenuous DOD or congressional support for his program usually elects a more conservative use of LRIP than the PM with strong support. The HELLFIRE and Javelin programs, for example, placed LRIP after IOTE, whereas the strongly supported MLRS and ATACMS initiated LRIP to produce articles for IOTE.

* **Articles needed for testing and available budget are the current major quantity drivers.** The number of units generally used in IOTE is small compared with the total units produced under LRIP. The majority of LRIP effort falls within the category of units required to establish a production base and permit an orderly increase to full-rate production. Available budget universally established the maximum quantity.

* **Use of LRIP is, and should remain, context dependent.** LRIP is an activity reserved for the latter part of the EMD phase. As such, the LRIP process is an effective way in which to validate a production line, produce articles for operational testing, and to finalize the technical data package prior to the Milestone III, production approval, decision. Each program may incorporate one or more of these uses as an objective of the LRIP phase. Depending on the program's objectives the resulting quantity can vary.

* **LRIP should be viewed as an extension of EMD and as such, no consideration should be given to meeting an IOC with LRIP articles.** All of the reviewed missile programs have met current statutes in their use of LRIP. In every case however, LRIP articles were, or will be used to meet an IOC date. This date can become the primary schedule driver, as it did in the ATACMS program. As such, pursuit of the IOC date may sacrifice some objectives of the LRIP phase.

* **Disciplined concurrent engineering (between design and production) is key to a successful LRIP phase.** DOD 4245.7M was issued in September 1985 to help Program Managers better understand the timing of the disciplines of design, test, and production. Use of production configured tooling, test equipment, production documentation, and production personnel when building EMD hardware is especially helpful.

B. RECOMMENDATIONS

There are several recommendations that can be drawn from the previous conclusions. The following are specific recommendations that DOD should consider.

- **DOD should consider establishing a Configuration Management (CM) position in each major program office.** Establishment and control of a firm production baseline is perhaps the greatest challenge to a PM while transitioning from development to production.

- **DOD should encourage greater contractor involvement in LRIP quantity decisions.** The majority of LRIP articles are categorized as the quantity necessary for production prove-out. The contractor can provide critical insight in determining this quantity and, therefore, should have greater input.

- **Greater attention should be placed on how program offices are determining their production quantity for LRIP.** The milestone decision authority should require that the minimum LRIP quantities be separately identified, documented and approved at the Milestone II, Developmental Approval, decision point and reaffirmed before entry into LRIP during production readiness reviews. LRIP articles should not be produced solely to meet an IOC date.

- **DOD should consider ways to promote better concurrent engineering in development programs.** The issuance of DOD 4245.7M in 1985 is apparently not enough. A contractor's prior experience with Government programs appears to be the primary learning tool to this discipline.

APPENDIX A

LOW-RATE INITIAL PRODUCTION QUESTIONNAIRE

The following questionnaire was used to gather information and facilitate interviews conducted during the course of this thesis research.

GENERAL INFORMATION

Program Name: ______________________

1. Weapon/System Function or Mission: ____________________

____

____

2. What is your definition of LRIP? ____________________

____

____

____

3. Does LRIP have a specific meaning in the context of your program? Please explain.

____

____

____

4. Why did (will) the program enter LRIP and what were (are) the objectives?

5. Describe the effect of LRIP on the overall program. For example, were (will) cost and schedule estimates (be) adjusted? Was IOC delayed?

6. Who (position, not name) was (is) involved in the decision to send the program through LRIP and who was the final authority?

7. How many LRIP systems were (are) being produced? How was this determined? What was your preferred number and why? The interest here is on determining the appropriate number of LRIP systems required to meet a specific objective (e.g., for operational test vs. to establish an initial production base).

8. Was the contractor involved in this decision process, and if so, how?

9. Would you consider LRIP to be an Acquisition Strategy i.e., was the LRIP phase planned from the outset?

10. Do you feel there is increased interest in LRIP as a procurement strategy? For what reasons?

COST AND SCHEDULE

11. How has LRIP impacted upon the cost of your program?

____

____

____

12. Indicate the initial and most current schedule estimates for the following program milestone dates:

	Initial Month/Year	Current Month/Year
Program Initiation:	___/___	___/___
Demonstration/Validation (Milestone I)	___/___	___/___
Full-Scale Development (Milestone II)	___/___	___/___
Low-Rate Initial Prod. (Milestone IIIa)	___/___	___/___
Full Production (Milestone IIIb)	___/___	___/___

13. When was (will) the decision made to go to LRIP?

Month/Year

Enter date: ___/___

TECHNOLOGY AND PERFORMANCE

14. Was (is) the technology advance sought in the overall program evolutionary (relatively small increase in technological advance building on the existing state of the art as represented by existing systems) or revolutionary (major innovative technological advance over current systems)?

___ Evolutionary

___ Revolutionary

15. What were (will be) the most difficult technical challenges in the overall program? ______________________________

____

____

____

16. Describe the role of LRIP in meeting these challenges.

____

____

17. Did LRIP have a positive or negative effect on your program? ____

____

____

18. What lessons did you learn from LRIP? ____________

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____

____

____

19. What additional information do you feel would be needed to help me fully understand the role of LRIP in your program?

____

____

____

____

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